Visualization of Thermal Waves from Optical Reflectance Spectra

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The word "thermal wave" commonly refers to the wave-like temperature field that is induced by a harmonic heating process. These waves were already used by Lord Kelvin and A.J. Ångström to investigate the thermal diffusivity of materials, but it is only since the early 1980's that they have been termed "thermal waves", arousing a remarkable clamor. The scientific community still debates to what extent thermal waves possess a true wave-like nature, even if their formalism is widely accepted and used to describe periodic temperature fields. In this paper we describe a simple method to visualize plane thermal waves traveling in a transparent medium. The principle is the following: a laser beam, modulated at a given frequency, excites a plane thermal wave in a transparent medium by irradiation of an opaque thin film coating. This traveling thermal wave causes a weak modification of the refractive index of the transparent medium. As a consequence the spectral distribution of the optical reflectance of the structure as probed with a white light beam or wavelength-scanned monochromatic beam is perturbed. A simple integral relationship has been found to calculate the change in the optical reflectance spectrum in the presence of the periodically time-varying temperature field inside the sample. To visualize the thermal wave we solve the inverse problem of computing the temperature field from the observed perturbation in the reflectance spectrum. We present this new inverse problem and related inverse techniques, and discuss the feasibility and the accuracy in the reconstruction of the thermal wave.